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METALLIFEROUS LATERITE IN NEW CALEDONIA

By W. M. Davis

Department of Geology and Geography, Harvard University

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A recent paper on lateritic ore deposits by W. G. Miller[1] gives among other matters an account of the composition of the nickel- and cobalt-bearing laterite of New Caledonia, but does not call attention to the physiographic relations of the laterite, probably because the physiography of the island has been little discussed in published articles. Even the manifest evidence of submergence given by its embayed shore line has hardly been mentioned by the students of its geology. The mature sea cliffs, which usually cut off the hard-rock highlands along the northeastern coast and which frequently descend, except for narrow fringing reefs, into ten or twenty fathoms of water, contrast strongly with the rounded hills and sloping lowlands of weaker rocks that dip gradually under sea level along the southwestern coast; but the contrast has only been treated empirically if at all in accounts of the island. Furthermore, the form of the northeastern cliffs, the depth of the reef-enclosed lagoon in front of them, and still more the form of the embayed valleys that interrupt the cliffs, all taken together, indicate that the cliffs were cut by waves while the island stood several hundred feet higher than now, and that this higher stand occurred during a subrecent period of the physiographic development of the island when the northeastern coast must have been unprotected by coral reefs for a time long enough for the cliffs to be worn back several miles; but these physiographic contributions to the historical geology of the island, not being attested by fossiliferous stratified deposits, appear to have been overlooked. As long as elements so important as these in the historic geology of New Caledonia land forms remain unstated, the origin of its superficial ore deposits will necessarily be unsolved.

The most significant features in connection with the ore deposits are the highlands on which they lie. Although the greater part of the mountainous island is of irregular form and varying altitude, there are certain districts,

particularly those occupied by serpentine rocks, which are characterized by rolling highlands of moderate relief at altitudes of 600, 800 or 1000 feet. These seem to be elevated peneplain areas; they are trenched by relatively steep-sided valleys, and are adjoined either by surmounting residual mountains, presumably formed of more resistant rocks, or by the lower hills and lowlands of the southwestern coast where weaker rocks prevail. The erosion of the subdued southwestern lowlands and of the narrow valleys in the highland areas has evidently been accomplished after the partial peneplanation of the island and its subsequent elevation, and during the same period of higher stand that witnessed the cutting of the sea cliffs along the northeastern coast, previous to the recent submergence by which the shoreline was embayed. The amount of the recent submergence may well have been from 600 feet or more; the previous upheaval of the northeastern side of the island, before its cliffs were cut, was probably at least twice as great, for the sea-cliffs today, in spite of being partly submerged, not infrequently still show 600 or 1000 feet of their height above water. The absence of all consideration of these inferences in the geological accounts of New Caledonia affords a striking illustration of the contrast between the older geological philosophy that based its theories only on the structure of rocks and their mineral and fossil contents, and the newer philosophy of geology which broadens the older one by adding thereto a reasonable consideration of surface forms and their evolution.

During my relayed trip around the island on three trading steamers, supplemented by local sail-boat excursions, in June and July, 1914, the rolling highlands were recognized as elevated peneplains at many points on both coasts. Where their vegetation is scanty, as is often the case, the soils of the highland slopes are laid bare in rain-washed gulleys which disclose their varied colors, dark or black at the surface and usually a strange mixture of vivid reds and ochres beneath. At certain points the open workings of the highland laterite mines were seen, and at one harbor where a steamer touched for an afternoon I had time to climb the slopes and inspect the excavations. The residual nature of the deposits was manifest enough. The boulders, referred to in Miller's paper as lying at the bottom of the loose deposits and as affording a rim or coating that is scraped off and added to the ore pile, are perhaps partly concretionary in origin, but some of them appeared to be incompletely decomposed rock kernels lying almost in place within a matrix of more disintegrated material. It is significant that the abundant hill-side detritus is not worked; ore of paying richness and quantity seems to be limited to the highland areas. It is further significant that, as is usual in such residual deposits, analyses of the highland ore deposits show a much higher percentage of nickel and cobalt than is found in the underlying serpentines.

In view of all this it seems reasonable to infer that the ore deposits are the result of surface enrichment by leaching and concentration during the later stages of the above-mentioned cycle of peneplanation, and that they have been undergoing removal rather than further accumulation and enrichment in the

later cycle of erosion introduced by elevation; the removal thus initiated is still continued in spite of the still later subsidence.

The general sequence of changes by which the present form of the island has been evolved from a subcontinental land of Tertiary or earlier time may be outlined as follows. A composite land mass of large, perhaps continental, extent, consisting hereabouts of deformed crystalline and Mesozoic rocks, was eroded to mountainous or moderate relief, *AB*, in the background block of figure 1; it was then reduced in area by down-warping, probably in tertiary time, whereby the surviving land area must have gained an embayed shore line, *C*, *D*, as in block 2. If coral reefs had previously existed around the border of the larger land, they must have been drowned by rapid submergence, for the

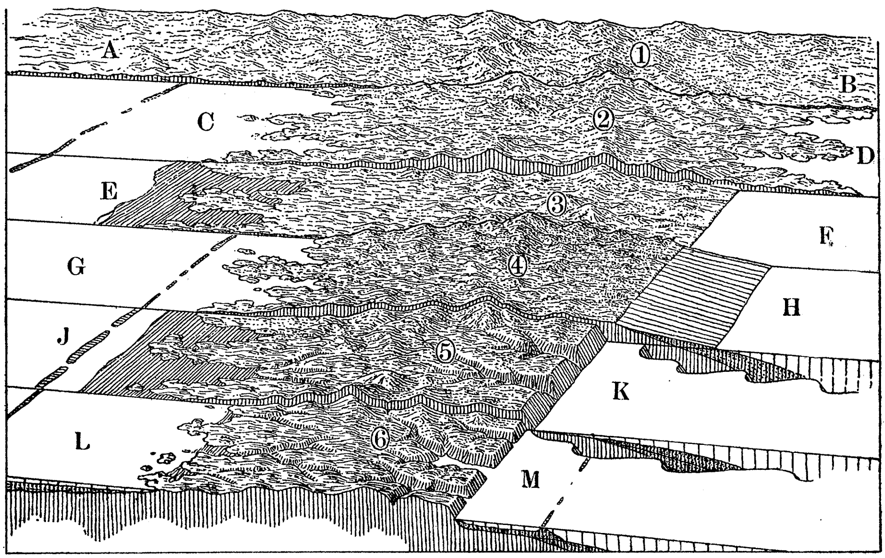

FIG. 1. THE PHYSIOLOGICAL DEVELOPMENT OF NEW CALEDONIA

adjoining seas are very deep. New reefs may have been formed in the later stages of submergence, enclosing a lagoon, *C*.

The reduced island of block 2 must have stood still long enough to suffer reduction to small or low relief, except in its areas of most resistant rocks, as in block 3; the serpentine areas were mostly reduced to peneplains at this time. The embayments formed in the shore line at the beginning of this cycle of erosion were presumably in time filled with deltas that advanced into the reef-enclosed lagoon, as at *E;* the deltas may indeed have grown so far as to overwhelm and smother the reef, whereupon it would be cut away by the waves which would in time attack the worn-down land, retrograding its peneplains in low cliffs and spreading the detritus from them and the rivers on the shallow floor of the adjoining sea, *F;* for this change from a reef-fronted and prograded coast of submergence in an early stage of an erosion cycle that

had been introduced by warping to a reef-free and retrograded coast in an old stage of the cycle is a most natural consequence of a long stationary period in the history of an island in the coral seas.

Another warping is then inferred, chiefly because the change from the sub-continental land of block 1 to a narrow island adjoined by deep seas on both sides, is not likely to have been accomplished in a single period of deformation. This warping must be supposed to have affected the island unsymmetrically, as in block 4, probably drowning any previously formed barrier-reefs along the southwestern coast, and re-embaying the shore line there, where a new barrier reef, *G*, would be developed, but this last point is not essential; at the same time the northeastern coast appears to have been uplifted, so that a coastal plain of marine sediments, such as may have accumulated in the shallow sea, *F*, was there added, as at *H*. The reason for the last inference is that the elevated peneplain areas along the northeastern side of the island were cut back in cliffs by the sea in the early stage of the cycle introduced by this elevation; and the simplest way of accounting for this is to suppose that the elevation here laid bare a narrow coastal plain, covered with loose sediments, on the shore line of which reef-building corals could not establish themselves, and on which the waves could therefore work unimpeded. No other supposition can so reasonably account for the abrasion of cliffs along one side of an island in the coral seas during the early stages of a subrecent cycle of erosion.

Block 4 is then gradually transformed into block 5, in which the weak-rock areas of the southwestern coast are again worn down to moderate relief, and the reef-enclosed lagoon is largely filled with delta plains, as at *J;* and in which the uplifted peneplains of stronger rocks along the northeastern coast are dissected by narrow valleys and cut back in high cliffs, as at *K*. A recent submergence has converted block 5 into block 6, drowning the previously developed delta plains of the southwestern coast, where the reef has grown higher and the sea has advanced farther than before on the lowland border, thus leaving the broad lagoon, *L*, of today between the young shore line of submergence and the barrier reef; the same recent submergence has partly drowned the cliffs of the northeastern coast, so that their valleys are now beautifully embayed, and a barrier reef has grown up from the sea bottom in front of them, as at *M*. It is chiefly upon the highland peneplains back of the cliffs of this coast, and upon similar highland areas which occur along the northwestern half of the other coast, that metaliferous laterites occur.

Abundant variations on the earlier stages of the foregoing scheme may be proposed. The changes here outlined are probably much simpler than the changes that have actually taken place, and some of the changes here indicated are very uncertain. For example the cutting back of the embayed coast, *D*, in block 2, to the low cliffs, *F*, of block 3, is by no means assured; but the unsymmetrical warping by which block 3 was transformed into block 4 seems to be essential as a means of reasonably providing for the development of sea cliffs in a relatively early stage of the cycle of erosion on one side of the island

where the rocks are hard, while no cliffs are developed on the other side of the island, even though the cycle of erosion on the weaker rocks that there prevail advanced in the same measure of absolute time to a late stage of development, when reef extinction and retrogressive abrasion are expectable occurrences. The prevention of cliff development on the southwestern coast is favored by assuming that the submergence which lowered block 5 to block 6 was caused by progressive subsidence. In any case, the general submergence by which block 5 is changed to block 6 is easily demonstrated. It is therefore in view of some such geologically modern sequence of moderate deformation and prolonged erosion as is here sketched, uncertain and shadowy in its earlier stages, better certified in its later stages, that the development of the ore-bearing laterites must be explained.

The enrichment of the present ore deposits could not have begun on the serpentine areas in the immature stages of the earlier cycle of erosion in which block 2 was worn down to block 3, for at that time the valley-side slopes, profiles 1, 2, figure 2, were steep enough, just as they are in the immature stage, profiles 1′, 2′, of the present cycle in the serpentine areas, to allow the

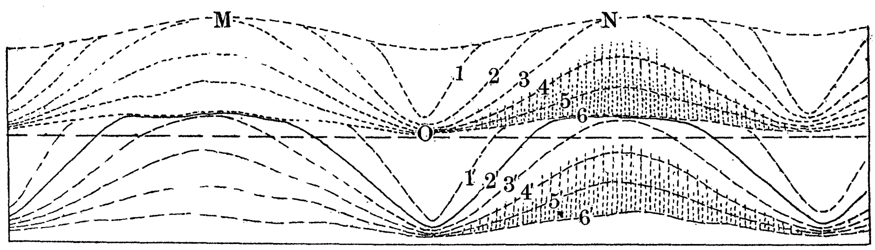

FIG. 2. RELATION OF ORE-BEARING LATERITE TO TWO CYCLES OF EROSION

removal of disintegrated rock about as fast as it was weathered. Even during the mature stage, profile 3, of the earlier cycle, removal rather than accumulation must have prevailed; but as the later stages of the cycle were reached, soil removal from the subdued hills, profiles 4, 5, between the wide-open valleys must have been much slackened; the thickness of the disintegrated materials there occurring and with it the surface enrichment of the metallic ores by downward concentration must have thenceforward increased as the subdued hills were worn down to the gentler and gentler gradients of old age, as in profile 6; and the area on which concentration was important must have been on the low swells between the broad valleys. If these inferences are correct, it follows that the nickel and cobalt content of the greater part, *MNO*, of the primeval rock mass has been carried away and deposited on the adjoining sea floor, and that the deposits now worked contain chiefly the concentrated savings from only a quarter or a sixth of the primeval total, shaded in the upper half of figure 2. This explanation traverses Glasser's supposition[2] that the serpentine masses have not been much eroded; for in view of their form alone, apart from the evidence of erosion given by ore concentration, that supposition seems untenable.

Again, the submature or mature main valleys, profile 2′, of the prentcyclees presumably excavated beneath the wide-open old valleys of the earlier cycle, have not as yet encroached greatly upon the ore-bearing part of the inter-valley highlands, profile 6. The encroachment and removal will be greater and greater as the main valleys of the present cycle are widened, profile 3′, (the recent submergence is not indicated here) and as branch valleys are extended headward into the highland by retrogressive erosion. Still later, profile 4′, the highland surfaces of the earlier cycle and their residual laterite cover will be completely worn away; but finally, when old age is again approaching, profiles 5′ and 6′, new deposits will again be formed by rock disintegration and ore concentration on the subdued and lowering inter-valley hills of the future, just as happened in the past.

The superficial laterite ores of the serpentine highlands in New Caledonia therefore seem to be local as to area of development and intermittent as to time of origin and duration of occurrence. The same relations presumably obtain in a general way regarding the limonite and bauxite deposits of our Appalachian valleys.

[1] *Report, Ontario Bureau Mines*, No. 26, part 1, 1917.

[2] Richesses minérales de la Nouvelle Calédonie, *Ann. des Mines*, 1903–04.

A COMPARISON OF GROWTH CHANGES IN THE NERVOUS SYSTEM OF THE RAT WITH CORRESPONDING CHANGES IN THE NERVOUS SYSTEM OF MAN

By Henry H. Donaldson

Wistar Institute of Anatomy and Biology, Philadelphia

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For a number of years the albino rat has been used for the study of growth changes which occur in the brain between birth and maturity.

As occasion offered, the results obtained from the rat have been compared with those from man, in order to determine how far the rat might be used for the study of the corresponding problems in man.

As all of these studies were in the field of growth, and as growth is a function of age, it became necessary in order to make the cross reference, to determine the equivalent ages of the rat and man.

Two observations were available for this determination.

1. The rat doubles its birth weight in 6 days, while man takes 180 days—giving a ratio of 1 to 30 days. From this it would appear that the rat was living 30 times as fast as man.

2. Again, a rat of 3 years is very old—so that I have ventured to compare a rat of this age with a man of 90 years. Once more the rat appears to be living 30 times as fast as man.